PRESCRIBED FIRE FOR PRECOMMERCIAL THINNING IN A FOUR-YEAR-OLD LOBLOLLY PINE STAND[1]

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Abstract.--A two-phase study was conducted to determine the feasibility of using prescribed fire to thin young, naturally regenerated loblolly pine stands. In Phase I, survival after winter backing, strip head, flanking, and spot fires was compared. Backing fires were chosen for Phase II on the basis of survival of the largest trees and uniformity of thinning. In Phase II, burning produced the effect of a thinning from below and reduced density from 6,800 to 2,850 stems per acre (58 percent). Crown scorch was heavy but needle consumption was infrequent. Much of the study area remained overstocked with few spots being understocked. Diameter growth of surviving trees was unaffected but height growth was reduced by 33 percent. Precommercial thinning of dense natural stands with fire shows promise but needs additional study before general recommendations can be made.

Keywords: crown scorch, needle consumption, South Carolina, nearest neighbor.

INTRODUCTION

Coastal Plain stands of loblolly pine (Pinus taeda L.) are often regenerated by natural means, whether by design or by accident. Since large seed crops are produced almost every year in this region (Langdon 1981), young stands are usually dense. On the Francis Marion National Forest, approximately 1000 acres of such stands are hand-thinned annually at a cost of $55 per acre.[3] Prescribed burning could be a less expensive method of precommercial thinning that would provide the additional benefit of protecting stands from wildfire at a younger age than is currently practiced.

Even though prescribed fire is generally not recommended for sapling-sized stands, its feasibility for precommercial thinning has been studied for several species. The first studies were with uneven-aged Ponderosa pine (P. ponderosa Laws.) stands (Weaver 1947; Morris and Mowat 1958; and Wooldredge and Weaver 1965). Because some areas were too heavily thinned while others were not thinned enough and height growth was reduced, a summary task force on fire in the Northern Rocky Mountains (Roe and others 1971) did not recommend prescribed burning for precommercial thinning in western pines. Muraro (1977) concluded that prescribed burning should not be conducted in lodgepole pine (P. contorta Dougl.) stands younger than 25- to 30-years-old due to a lack of surface fuels and susceptibility to Ips beetle attack.

In the South, precommercial thinning with fire was recommended by McNab (1977) for loblolly pine stands and Nickles and others (1981) for shortleaf pine (P. echinata Mill.) stands with a large range of tree sizes. In both studies, burning acted as a thinning from below with high mortality only in the smallest size classes. A high negative correlation existed between mortality rates and bark thickness at the root collar.

For prescribed burning to be a successful tool for thinning young pines, data is needed to describe how various burning techniques affect survival, growth, and spacing of stands over a wide range of conditions. This paper describes the results of a two-phase study of the feasiblilty of using prescribed fire to thin young, naturally regenerated loblolly pine stands. The first phase compared four burning techniques and selected the best on the basis of survival of largest trees and uniformity of thinning. The burning technique selected in the first phase was used in the second phase to study survival, growth, and uniformity of stocking.

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STUDY AREA

The study is located on the Santee Experimental Forest in Berkeley County, South Carolina at an elevation of approximately 25 feet above mean sea level. Soils are Aeric Ochraquults of the Wahee series and are somewhat poorly drained and slowly permeable. Slopes range from 0 to 4 percent. Site index for loblolly pine at age 50 is 86 feet.

At the time of study establishment (Winter 1986), the stand was 4-years-old consisting almost entirely of loblolly pine saplings resulting from seeding from adjacent stands. Diameters at breast height ranged from less than 0.5 inch to 2.6 inches with a mean of 0.6 inch. Tree heights ranged from less than 5 feet to 15.6 feet with a mean of 7.3 feet. Stocking was at aproximately 6,800 stems per acre.

The previous stand was clearcut in November 1981 after a winter prescribed burn and 3 annual summer burns. Logging slash was burned the following March. The area was then planted with loblolly pine seedlings on an 8 by 12 foot spacing. However, survival of planted seedlings was less than 20 percent due to an infestation of Pales weevil. After planting, the area was fertilized with 250 pounds per acre of 0-46-0 triple superphosphate.

PHASE I

Test of Burning Techniques

Four burning techniques were tested to determine the most feasible for thinning a sapling-sized stand. Each of four study plots, 130 by 60 feet in size, was burned by either a backing fire, strip headfire, flanking fire, or a spot fire with a 6 by 6 foot spacing between spots. Burns were conducted on January 17, 1986, 6 days after a rainfall of 0.56 inch. Burning began at 12:00 pm with a temperature of 70 degrees F. and a relative humidity of 42 percent. Winds were from the southeast at a speed of 4 to 7 miles per hour. Surface fuels were light on all plots. However, dried broomsedge (Andropogon virginicus L.) covered most of the area and carried the fires.

A strip headfire was conducted by setting a backing fire followed by strips at 5 to 8 foot intervals. Flame heights remained at 2 to 3 feet except where strips came together and flames overtopped some trees. This variability in fire intensity was intentional to kill some trees while leaving others.

The backing fire traveled into the wind at a rate of 1.5 feet per minute. Flame heights remained uniform at 1 to 2 feet with no evidence of flames reaching the lowest tree limbs. The backing fire was intended to girdle the stems of small diameter trees while leaving larger trees alive.

The flanking fire began with a backing fire perpendicular to the wind, followed by several flanks aproximately 15 feet long set parallel to the wind. Resulting flames were variable in height, ranging from 1 foot or less where flanks backed into the wind to levels above treetops where flanks came together. As with a strip headfire the variable fire intensity was intentional to kill only a portion of the stand.

The spot fire was started first with a backing fire, then spots were set on a 6 by 6 foot spacing while moving into the wind. The method was intended to cover the plot with fire quickly while putting spots close enough to prevent flames of high intensity. However, this method produced a high intensity fire over the entire plot with flames overtopping most trees. Therefore, this method was not considered feasable for precommercial thinning in such young stands and was not included in subsequent measurements.

An estimate of survival was conducted 2 weeks after burning in plots where backing, strip headfire, and flanking fires were used. A random sample of 100 trees was selected in each plot and the cambium of each tree observed. Trees were assumed to be dead or dying if more than 50 percent of the circumference of the cambium at ground level was brown. Each tree was tallied as alive or dead and total height was measured.

Results

Mortality by height class is compared for three burning techniques in Figure 1. For all burning techniques, mortality was high in the two smallest size classes (less than 9 feet and 9 to 12 feet) and relatively low among the largest trees (over 12 feet), thus producing the effect of a thinning from below. Among the largest trees, survival was highest with the backing fire (68.7 percent) as compared to the flanking fire (50 percent) and strip headfire (57.1 percent). Since the flanking and strip headfires produced variable fire intensities, some spots were too heavily thinned while others were not thinned enough. Thinning was most uniform over the entire plot with the backing fire. Therefore, backing fires were selected for use in Phase II of this study.

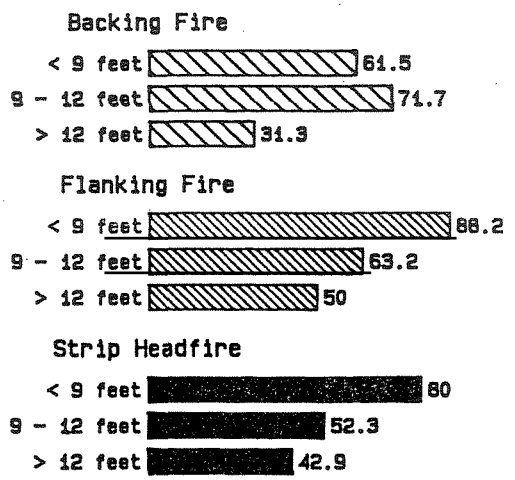

Figure 1.--Percent mortality by height class two weeks after winter prescribed fires of various techniques.

PHASE II

Study Design

The study was established as a split-plot randomized complete block design with five replications, two whole plots per replication, and two subplots per whole plot. Whole plots were 131 feet square (0.4 acre) and assigned to blocks on the basis of having similar pretreatment stocking and size distributions. Each plot within a replication was randomly selected to be burned or left as an unburned control. Whole plots were split into fertilized and unfertilized subplots to observe the interaction of burning with fertilization, which should accelerate the growth of dominant trees. Fertilized subplots received triple superphosphate and urea at levels of 25 pounds P and 200 pounds N per acre.

Burning Conditions

Backing fires were conducted on February 3, 1986, 4 days after a rain of 0.42 inch and 7 days after a rain of 0.91 inch. Burning began at approximately 12:30 pm with a temperature of 70 degrees F. and a relative humidity of 38 percent. Winds were from the southwest at 3 to 5 miles per hour. Fuels along the ground were light and moist but the entire study area was covered with dried broomsedge which carried the fires. Flames were generally 1 to 3 feet in height (6 to 26 Btu/second/foot using Byrams flame length index, Brown and Davis 1973). Occasionally, flames reached 4 to 5 feet in height (116 to 188 Btu/second/foot) where vertical fuels (broomsedge and needle drape) were heavy. The mean rate of spread over all replications was 3 feet per minute. Burning was concluded at approximately 1:30 pm.

Measurements

Measurements were taken in each of the five replications to examine the degree of crown scorch and needle consumption resulting from backing fires, survival by size class, uniformity of stocking before and after burning, and growth of survivors in burned and control plots. In May 1986, 3 months after burning, degree of crown scorch and needle consumption were estimated for every tree over five feet tall on a 0.04 acre sample plot in each of the 10 burned subplots. For each tree, the height to the bottom of the crown, highest point of needle consumption, highest node with scorched needles, total height, and dbh was measured. Crown scorch and needle consumption were expressed as a percentage of the length of the crown before burning. Each tree was tallied as alive or dead to compare size distributions before and after burning and to relate mortality to degree of crown damage.

Stocking levels before and after burning were estimated at 54 randomly selected points throughout each burned plot to examine uniformity of thinning. The nearest neighbor technique (Clark and Evans 1954) was used by measuring the point to the nearest tree (either alive or dead) and to the nearest live tree. Measured distances were converted to point estimates of density by the method of Thompson (1956). Measurement of distance to the nearest tree and the nearest live tree allowed a comparison of densities before and after burning.

The effect of burning on tree growth was studied by comparing dbh and height growth between burned and control plots. In each 0.04 acre sample plot, both in fertilized and unfertilized subplots, the dbh and height of each of 40 trees was measured at the beginning and end of the 1986 growing season. Sample trees were selected as the largest on each sample plot since those would be most likely to survive the burning treatment and reach rotation age. Mean subplot dbh and height growth were compared by analysis of variance.

RESULTS AND DISCUSSION

Mortality and Size Distribution

Prescribed burning reduced the total number of stems per acre from 6,800 to 2,850 (58 percent). The highest mortality rates were in the lower diameter (Figure 2) and height (Figure 3) classes. Mortality was 88 percent and 53 percent in the 0.2 inch and 0.6 inch diameter classes, respectively. The 6 foot height class had 80 percent mortality while the 8 foot class had 47 percent. Mortality in the upper dbh and height classes was near zero.

The pattern of thinning was silviculturally desirable, resembling a thinning from below. Burning changed the diameter and height distribution from a reverse-J pattern, with large numbers of small trees, to a bell-shaped pattern with medium-sized trees being most frequent (Figures 2 and 3). As a result, mean tree dbh increased from 0.6 inch to 0.9 inch and mean tree height increased from 7.3 feet to 8.4 feet. Even though burning substantially reduced the total number of stems, the stand was still dense. A burn of somewhat higher intensity may kill more trees in the small size classes, thus better improving growing conditions for the larger survivors. These results closely resemble those of McNab (1977) in a much older (17.5 years) loblolly pine stand.

Crown Damage and Mortality

Crown damage due to backing fires was heavy in all study plots. Over 5,500 trees per acre (81 percent) recieved at least 40 percent crown scorch while over 4,200 trees per acre (62 percent) were totally scorched. Even though crown scorch was heavy, the incidence of needle consumption was low. Only 26 percent of all trees showed evidence of needle consumption.

Several studies have shown mortality of pole-sized or larger pines with severe crown scorch (Storey and Merkel 1960; Methven 1971; Villarrubia and Chambers 1978; and Waldrop and Van Lear 1984). When working with trees generally less than 20 feet tall, Wade (1985) found that degree of needle consumption was a better predictor of mortality than crown scorch. He showed that survival was

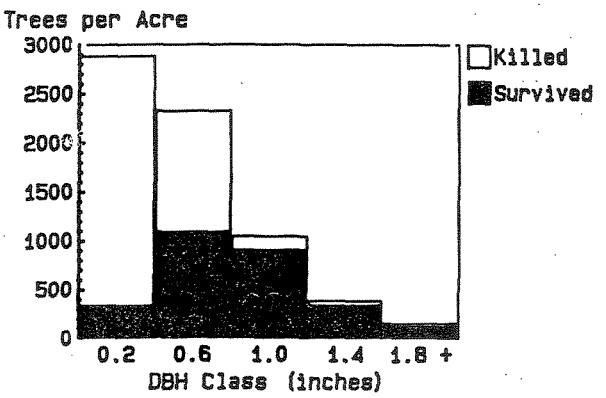

Figure 2.--Change in diameter (dbh) distribution of a 4-year-old loblolly pine stand after a winter backing fire.

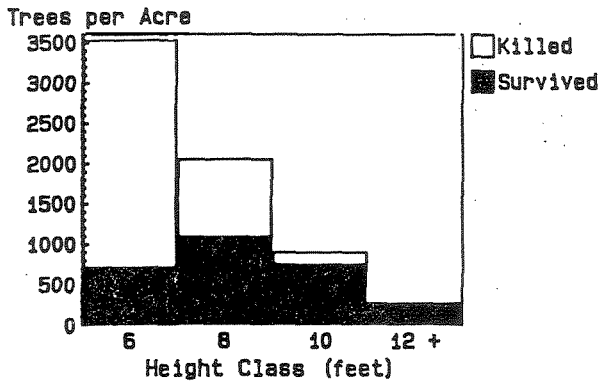

Figure 3.--Change in height distribution of a 4-year-old loblolly pine stand after a winter backing fire.

less than 50 percent among trees with 20 percent needle consumption or more. Figure 4 shows the rate of mortality of trees with various degrees of crown scorch and needle consumption in this study. Mortality was low among trees with less than 80 percent crown scorch. Above the 80 percent crown scorch level, mortality becomes very high. Similar to Wade's findings, mortality was over 50 percent when needle consumption was 20 percent or more.

Mortality occurred even at low levels of crown scorch (Figure 4), indicating that crown damage may not be the only cause of mortality. McNab (1977) and Nickles et al. (1981) found a strong correlation between survival and bark thickness at the root collar, suggesting that mortality was caused by stem damage. Although not conclusive, these data suggest that mortality after a backing fire in a sapling-sized stand may be caused by both crown and stem damage.

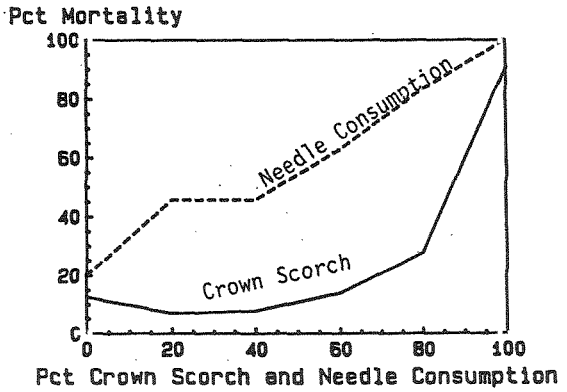

Figure 4.--Percent mortality by percent crown scorch and needle consumption after a winter backing fire.

Uniformity of Stocking

The percentage of the total study area stocked at various levels before and after burning is shown in Table 1. Before burning, the majority (80.1 percent) of the study area was overstocked. For the purpose of this paper, overstocked is defined as 1600 stems per acre or more. After burning, the majority of the area (54.3 percent) was stocked at levels of 400 to 1,200 stems per acre, which are acceptable for many forest products. The remaining 45.7 percent of the area was still overstocked with densities as high as 12,000 stems per acre, yielding a mean of 2,850 stems per acre. However, a single prescribed backing fire effectively lowered stocking levels over the entire study area. In addition, areas that were understocked (fewer than 400 stems per acre) were essentially absent. The absence of understocked areas indicates that backing fires are preferable to flanking and strip headfires where hot spots and, therefore, areas of high mortality are more frequent.

Table 1.--Percentage of the total study area stocked at various densities before and after burning.

Stems per Acre	Before Burning	After Burning
	(Pct)	(Pct)
400	3.5	27.9
800	10.0	17.1
1200	6.5	9.3
1600+	80.0	45.7
Total	100	100

Tree Growth

When crown damage from burning is high, as with this study, pine growth is often reduced (Johansen 1975 and 1984; McCulley 1950). Johansen and Wade (1985) reported the loss of an entire year's diameter growth in trees with severe crown scorch. In this study, an analysis of variance showed no significant differences in mean diameter growth of sampled trees in burned and unburned study plots, regardless of whether they had been fertilized (Table 2). Fertilization significantly increased diameter growth on burned and unburned plots.

Table 2.--Diameter (dbh) and height growth one growing season after a winter backing fire.

Treatment	DBH Growth (in)	Height Growth (feet)
Burned - No Fertilizer	0.31 a[1]	1.8a
Unburned - No Fertilizer	0.37 a	2.7 b
Burned - Fertilized	0.47 b	2.0a
Unburned - Fertilized	0.48 b	2.6 b

[1] Means followed by the same letter within a column are not significantly different at the 5 percent level.

Height growth of sample trees was adversely affected by a single winter backing fire (Table 2). In plots that were not fertilized, height growth averaged 2.7 feet in unburned controls the year after burning as compared to only 1.8 feet in burned plots. Fertilization had no affect on height growth which is consistant with the findings of McKee and others (1986).

Since burning reduced height growth but not diameter growth, it is assumed that in highly scorched trees carbohydrates stored over winter were used for needle production and some diameter growth, rather than stem elongation. Therefore, height growth may have been minimal during the first flush of buds and trees in burned plots lagged behind those in control plots. A close comparison of the number of flushes and the stem length between flushes of trees in burned and control plots would give better insight into the effect burning had on height growth.

Even though some height growth was lost the year after burning, the loss was less than expected. In unfertilized plots, height growth was reduced by 33 percent in burned plots as compared to controls. In addition, competition among trees will be grealty reduced. Therefore, growth rates of individual trees can be expected to be greater in burned plots than in controls during future years. Close monitoring of tree growth and stand dynamics in these study plots over the next few years will provide a longer-term evaluation of prescribed fire for precommercial thinning.

SUMMARY AND CONCLUSIONS

A comparison of backing, flanking, spot, and strip headfires showed that each acted as a thinning from below with high mortality in small tree size classes. Backing fires provided the highest survival rates among the largest trees and the most uniform thinning throughout the study plot. Therefore, backing fires were chosen for continued study in this natural 4-year-old loblolly pine stand.

A winter backing fire reduced the number of stems per acre from 6,800 to 2,850. The pattern of thinning was silviculturally desirable since the diameter and height size distribution was changed from a reverse-J to a bell-shaped pattern. Also, mean tree height and diameter were increased. Crown scorch was high throughout burned plots but needle consumption was infrequent. Mortality was most common among trees with at least 80 percent crown scorch and/or some degree of needle consumption. Burning improved the uniformity of stocking since understocked areas were esentially absent and overstocked areas were less frequent than before burning. However, almost half of the area remained overstocked. Diameter growth during the year after burning was not affected but height growth was reduced by 33 percent (2.7 feet in control plots vs. 1.8 feet in burned plots).

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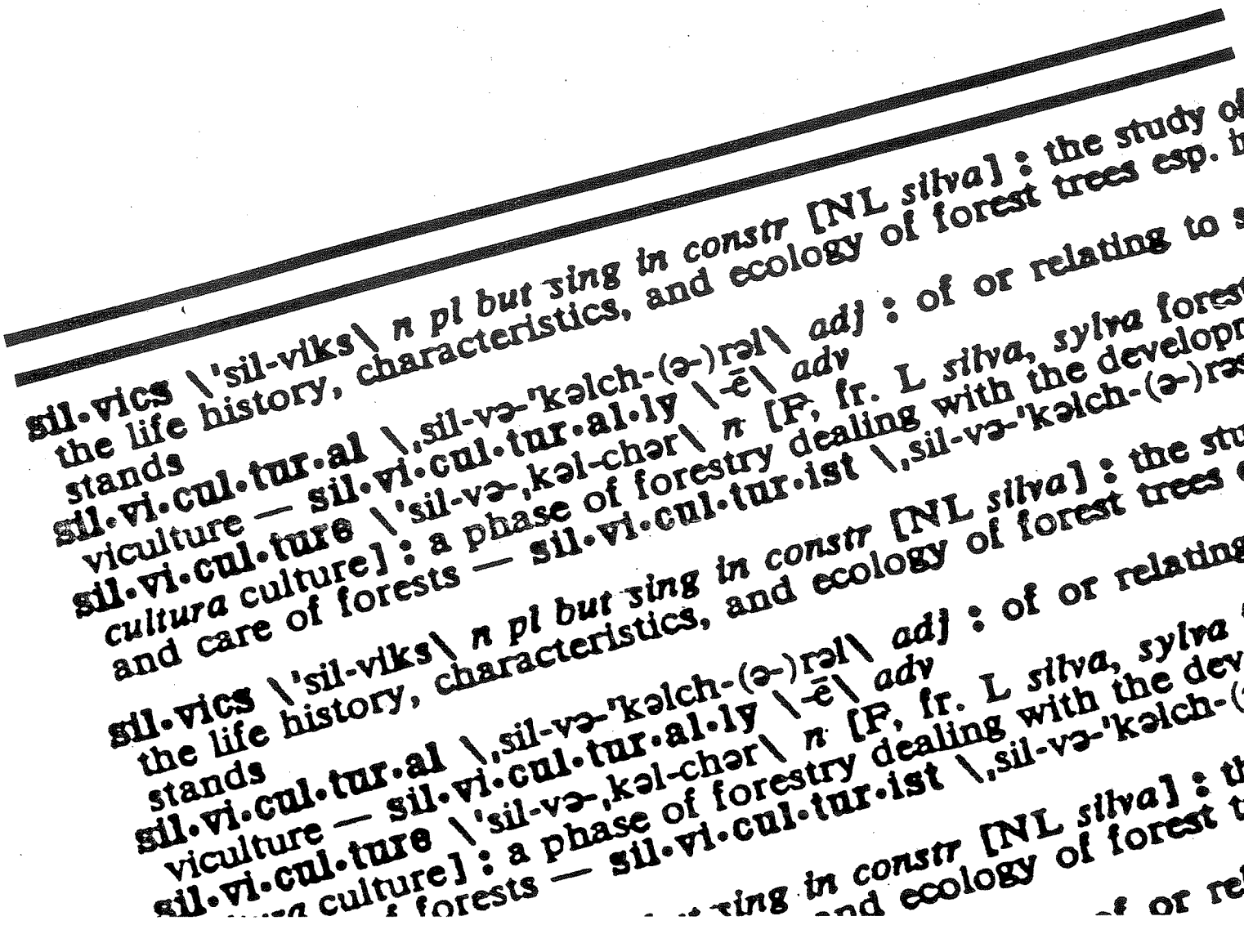

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Three abstracts and 93 papers are presented in 13 categories: Pine Regeneration, Prescribed Fire, Hardwood Regeneration, Pine-Hardwood Regeneration, Seedling Production, Soil-Site-Stand Relationships, Silviculture-Economic Relationships, Interactions and Influences, Site Preparation, Management of Established Stands, Growth and Yield, Pest Management, and Vegetative Management. In addition, three poster presentations are summarized, and five papers from the general session on World Forestry Trends Affecting Southern Silviculture are included.

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